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ABSTRACT

Tasks involved in paired associate learning (attention, perceptual learning, visual and auditory memory, response learning, and stimulus-response connections) are identified as some of the same skills and strategies involved in learning to read. Two studies on visual memory, the developmental lag hypothesis, and reading ability are examined to show that memory strategies and the ability to encode these are important factors in visual memory and that good readers are superior to poor readers in differentiating hard to distinguish stimulus terms in paired associate learning tasks. Good readers are thought to have a superiority in perceptual learning and recall which transfers to reading subskills. Studies on attention, acquisition and transfer are examined along with models of memory and studies on the role of distinctive feature training in acquisition and transfer. The author concludes that attention and memory are active processes which involve the use of strategies and which undergo developmental changes. Teachers are urged to teach paired associate learning as a multistage process beginning with perceptual learning tasks in order to improve visual memory skills. Goals for beginning readers are said to be accuracy and automaticity in the following successive skills: distinctive feature learning, schemata (chunk) learning, and the making of stimulus-response connections. (GW)

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ATTENTION AND VISUAL MEMORY IN READING ACQUISITION*

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Research, Development and Demonstration
Center in Education of Handicapped Children
Minneapolis, Minnesota

November 1971

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November 1971

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The long term objective of the Center is to improve the language and communication abilities of handicapped children by means of identification of linguistically and potentially linguistically handicapped children, development and evaluation of intervention strategies with young handicapped children and dissemination of findings and products of benefit to young handicapped children.

ATTENTION AND VISUAL MEMORY IN READING ACQUISITION*

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In this paper an argument will be made indicating that visual memory deficits, which are associated with poor reading, may originate at the perceptual learning stage. In order to improve visual memory a procedure is suggested for facilitating perceptual learning.

*Appreciation is extended to Dr. David LaBerge, who was instrumental in developing and testing many of the ideas and procedures contained in this paper.

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Paired-Associate Learning as a Multi-Stage Process

In the beginning stages of learning to read, there are several types of skills which the child is called upon to master which, in essence, are paired-associate learning tasks. For example, the child may be required to learn letter names, letter sounds, grapheme cluster sounds and oral responses for whole words. In each of these tasks, the student is given a printed verbal stimulus to which he must learn to associate a verbal response. The relationship between paired-associate learning and reading, as well as academic performance, in general, has been documented (Otto, 1961; Stevenson, et al., 1968). In fact, paired-associate learning ability is a better predictor of reading achievement than IQ (Anderson and Samuels, 1970).

Before proceeding, I should make this point clear. I do not mean to imply that learning-to-read is a paired-associate process. What I do mean is that there are a number of skills and strategies which must be learned in reading, some of which involve paired-associate learning. In fact, for some children, early failure in reading may come because they do not master the paired-associate reading tasks.

Furthermore, if we consider the relative importance of attention, visual memory, and paired-associate learning in beginning reading as compared to skilled reading, I think we would find they are more important in the beginning stages. Once the beginning sub-skills are mastered, then other systems increase in importance, such as the ability to predict from context and to use minimal visual cues in

recognition. Singer (1970), for example, while examining variables other than the ones being discussed here, has produced evidence showing the shift in importance of a particular system, skill, or strategy as one advances from beginning to more advanced stages in reading.

Historically, paired-associate learning was considered to be a simple, single-stage process. Continued analysis revealed that contrary to early assumptions, associational learning was a complex, multi-stage phenomenon. Gibson (1940) detailed the importance of stimulus learning. Underwood and Schulz (1960) have emphasized response learning and S-R hook-up stages. Samuels (1971) presented evidence for the role of attention, perceptual learning, visual and auditory memory, and mediational stages in paired-associate learning. Various multi-stage models of paired-associate learning can be found in Keppel's (1968) review.

Visual Memory, the Developmental Lag Hypothesis, and Reading

The role of visual memory deficits in reading difficulty has long been suspect but until recently, with no supporting evidence. Orton (1928) noted that children experiencing reading difficulty often confused letters which were similar in appearance but which differed in orientation, a condition which he called "strephosymbolia" (i.e., twisted symbols). Although no supporting evidence was provided, Benton (1962), Rabinovitch (1962), and Money (1966) claimed that poor visual memory was implicated in reading difficulty.

Given our present sophistication regarding the complexity of

paired-associate learning and the realization that some of the reading sub-skills require paired-associate learning, on logical grounds alone it is easy to understand why poor visual memory would be suspect in cases of reading difficulty. Bernbach (1967) and Martin (1967) have recently underscored the importance of recognition memory in paired-associate tasks. They found that on any given presentation, if the stimulus is not recognized, the probability of a correct response remains at the chance level, regardless of how many times the correct response was given on the previous occasions.

While there is increasing evidence to support those who would implicate poor visual memory as a factor in reading difficulty, nevertheless, some of the assumptions regarding visual memory itself are open to criticism. For example, there are those who look upon visual memory as a static process, a process analogous to imprinting an image on a photographic plate. As mentioned earlier (Orton, 1928), some believe that the visual memory deficit of poor readers is manifest by left-right orientation confusion. The developmental lag hypothesis (Lyle and Goyen, 1968) postulates that the visual memory of poor readers improves with age. Although there is evidence to support this viewpoint, what is criticized here is the implication that "time," and not what happens during the passage of time, brings about the improvement in memory. Finally, because the process underlying visual memory is not well understood by many who write curriculum materials for beginning reading, we can find visual discrimination training programs used in schools which are premised on the belief that any

kind of discrimination training is useful. Under testing, many of these programs have failed to demonstrate any transfer to reading.

Before reviewing the literature on the role of attention and memory in reading, it might be useful at this point to present two studies which investigated visual memory and reading.

Lyle and Goyen (1968) compared good and poor readers on visual recognition memory. They also investigated their orientation errors and the notion that usual memory deficits are more severe at early grade levels than at later grade levels which has been called the "developmental lag hypothesis". In order to test these hypotheses, matched groups of good and poor readers who were 7.3 and 9.1 years of age were given tests of visual memory. The tests consisted of showing the child a stimulus card with a letter or figure on it. Then it was withdrawn, and a multiple-choice test card was shown. The test card had the correct choice along with the distractors, one of which was a reversal of the correct choice.

Lyle and Goyen found recognition memory was less accurate for the poor readers at both grade levels. In addition, they obtained an age by reading group interaction. The older poor readers, though still performing significantly less well than the good readers, were catching up in accuracy of recognition memory. This improvement in recognition memory for the older group supported the developmental lag hypothesis. Whether the "catching up" was the result of neural maturation or the acquisition of attention and memory strategies, was not discussed.

The analysis of orientation errors in the Lyle and Goyen study

revealed that significantly more orientation errors were made by the younger poor readers than by the better readers. When the good and poor readers were compared in the older group, no difference was found in orientation errors. While these data support the developmental lag hypothesis, one wonders what changes over time. If the change represented more sophisticated strategies for handling perceptual learning and visual memory problems, this would be useful knowledge.

The second study on visual memory was done at my laboratory by Anderson (Anderson and Samuels, 1969). The subjects in our study, who were approximately the same age (7.6 years) as the younger group in the Lyle and Goyen study, were divided into good and poor readers. Our method for collecting visual recognition memory data consisted of showing six Gibson letter-like forms (called "standards") one after another. Immediately after, the visual memory test was given. On the test, the six Gibson standards and their transformations were shown in random order. The task on the test was to say "old" if the standard was shown and "new" if any of the transformations appeared. This procedure was repeated for six repetitions, always with the same standards but with different transformations.

In addition to the recognition memory tests, the students were given two tests of paired-associate learning. The two paired-associate learning tasks differed primarily in difficulty of visual perception learning. In the easy task, 5 distinct colors had to be associated with the vowels A, E, I, O, and U. In the difficult task, a Gibson figure (which had not been used in the memory task)

and three of its transformations (left-right, up-down, 180°) had to be paired with common words like cup, bat, dog, and pen.

The intercorrelations of our findings are shown in Table 1. Looking at this table, several points worth mentioning emerge. First, IQ and visual recognition memory (VRM) are not significantly correlated. Second, the total reading score on a standardized test and visual memory are significantly correlated (r=.31). Since the total reading score is comprised largely of items which bear no relationship to the skills we are concerned with in regard to the decoding process, we are depressing the true relationship. If we look at visual recognition memory and paired-associate learning, we find they are significantly correlated (r=.57). This correlation between visual memory and paired-associate learning is probably a more accurate reflection of the role of visual memory in beginning reading than the total reading score. The final point, is that the correlation between visual memory and association ability (AA) was significant (r=.26). The Association ability test was a simple paired-associate task matching colors to vowels. Thus, we find that visual memory is related to paired-associate learning, even when the stimulus terms are easy to discriminate, but when the stimulus terms are difficult to discriminate, the correlation is increased impressively.

Table 1 here

Comparing our findings to the Lyle and Goyen data, our findings lend only partial support to what they found. As in their study, we

found good readers were significantly superior to poor readers in visual recognition memory. However, this superiority came about in a peculiar way. Good readers were superior only in the ability to recognize a standard.

When transformations of the standards were shown, good and poor readers were equal. As a matter of fact, contrary to popular assumptions comparing good and poor readers, there was no essential difference in the percentage of errors given to up-down, 180°, and left-right reversal transformations. (see Figure 1B, Table 2)

Figure 1 and Table 2

Our findings failed to support the contentions of Lyle and Goyen (1968) and Orton (1928) that poor readers have a special problem with left-right reversal transformations. Good and poor readers in our study had similar problems with all transformations. It is interesting to note in the Lyle and Goyen study that they found no difference in reversal errors in their older group, only in their younger group. The fact that in comparisons of reversal errors, our younger subjects were performing on transformation problems the way the 2 year older group was performing in the Lyle and Goyen study, suggests the developmental lag hypothesis of the Lyle and Goyen is not simply a neural maturation phenomenon. Based on our observations, Anderson and I contend that memory strategies such as being able to note relevant feature differences among stimuli and the ability to encode these are important factors in visual memory, and improvements in memory over time may result from the acquisition of improved strategies.

The final point to be made relates to the significance of the finding that good readers are superior to poor readers in ability to recognize the standard. To explain the significance, let me draw an analogy. Imagine our good and poor readers at a party where they are introduced by name to six people. We are going to compare how quickly the two groups learn the names of six people whom we will designate as our target individuals. Unknown to our readers, each of the six people to whom they are introduced has a twin who is similar in appearance but not identical. From what we know about our good and poor readers, they will be equally confused by the twin who is similar. The good readers, however, are superior in recognizing the six target individuals. Now, the purpose of the game is to recognize the six target individuals, and this is just where our good readers excel. Based on our data, the good readers are a good bet for learning the names of the six target individuals, because of their superiority in recognizing them. In a similar fashion, the good readers do better at learning letter names, sounds and oral responses which go with printed words partly because of their superiority in recognizing a previously seen stimulus.

We have data from our study showing no difference between good and poor readers in paired-associate learning when the stimulus terms were easy to discriminate. But, when the stimulus terms were difficult to discriminate the good readers were superior. This superiority in perceptual learning and recall transfers to the reading sub-skills. As Bernbach (1967) and Martin (1967) explained, the ability to recognize a stimulus as one which has been presented before is absolutely essential in paired-associate learning.

Attention, Acquisition and Transfer

Having discussed in detail the two studies on visual memory and reading, the time has come to review some of the current findings regarding the role of attention and memory. Psychologists have long considered attention to be so essential to learning that without it there can be no learning. However, the research on attention indicates that there are different ways of studying attention. For example, one can look at overt attentional processes, that is, does the student orient himself towards a stimulus source which is related to an instructional objective. Lahaderne (1968) found a significant correlation between attention and reading achievement in a fifth grade class. One cannot infer directionality from this finding since it is possible that poor reading led to inattentive behavior. To test this relationship between attention and reading before a long history of reading failure could have its affects, Turnure and I (1971) replicated Lahaderne's method in first grade classes and supported her findings. What is interesting to us is that when teachers are asked why Johnny succeeds in reading, the teachers attribute the success to their skills as teachers. When asked why Johnny fails in reading, they attribute the failure to outside causes such as lack of readiness or dyslexia rather than to a factor such as attention, which they can control with proper training. There is evidence to indicate that students who are low in achievement seem to be more distractable (Baker and Madell, 1965; Silverman, Davids, and Andrews, 1963).

Another dimension of attention relates to focal attention.

Zeaman and House (1967) have put forth an extremely interesting explanation of one of the reasons why there are differences in learning ability between retardates and normals. They have evidence which indicated that for some learning tasks the retardate does not where to focus attention during early learning trials. Once the retardate discovers the relevant dimension, his learning curve is similar to the normal's.

Where the learner focuses attention and what cues he selects, whether focal attention is directed at a relevant dimension of the stimulus complex, has important implications for reading. For example, Samuels and Jeffrey (1966) found that if beginning readers were given words to learn to read by the whole word method which were highly discriminable from each other, learning was rapid because incidental cues such as first letter or last letter only were used. At transfer, when different words having the same first or last letter were presented, the students tended to mistake them for words on the original list. We can infer from this that reading methods which begin with the whole word approach and use words which are easily discriminated from each other, will produce rapid initial learning followed by confusion. Classroom teachers report rapid learning of a small sight vocabulary followed by a plateau. The plateau probably represents that point at which the student finds his use of irrelevant cues (ex., single letters, length) can no longer produce the correct verbal response.

If words are printed in color, the learner may focus attention on the color and not letter shape (Samuels, 1968). Although rate of

learning the word in color may be impressively rapid, when the incidental color cue is removed, and what is left is the letter printed in black, the response is lost. We find rapid learning at the expense of transfer. Design of curricular materials and methods in reading must consider problems of focal attention and transfer.

Role of Distinctive Feature Training in Acquisition and Transfer

Closely related to focal attention are the investigations of distinctive feature learning. In order to determine what the distinctive features were of upper-case letters, Gibson, et al. (1963) presented capital letters to four-year-old children. Their task was to select a letter from among several which matched a standard. An analysis of the mistakes indicated that the children tended to confuse letters which shared similar distinctive features. Thus, letter "O" tended to be confused with "G", and "Q", and "U". From these mistakes a confusion matrix was constructed indicating which letters share distinctive features. Popp (1964) did similar work with lower case letters. Gibson, Schapiro, and Yonas (1968) used same-different reaction times to letter pairs and were able to diagram the feature similarities of upper-case letters.

Several studies show the transfer effects of distinctive feature training. Jeffrey (1958) and Hendrickson and Muehl (1962) had children make a right motor response to "b," and a left response to "d." Children who had this motor response training were superior to their controls in learning to name these letters. These results were interpreted to indicate the importance of motor responses as a

mediational factor in associational learning. Today these same results would be interpreted to mean that in order to make the correct motor response, attention had to be focused on the relevant dimension of difference between the letters.

Pick (1965) gave kindergarten children training on noting distinctive features of letter-like forms. She found these children made fewer errors on a transfer task in which the stimuli, though different in appearance, contained the same distinctive features as found in training.

In the Pick study, the visual discrimination training was given by means of simultaneous matching-to-sample. She found that under simultaneous presentation of stimuli, distinctive feature learning occurred, for general purposes, to the exclusion of schemata learning. In a later study (Pick, Pick, and Thomas, 1966), where training conditions included simultaneous as well as successive matching-to-sample, they found that distinctive feature and schemata learning occurred respectively.

Samuels (1969) found delayed matching-to-sample visual discrimination training on high similarity figures, which required matching from memory, resulted in superior paired-associate learning in comparison to a group which got simultaneous training.

Ackerman and Williams (1968) also found that a training task requiring discriminations from memory resulted in reliably better learning on high similarity trigrams. Similarly, Williams (1969) found that kindergarten children trained to discriminate distinctive features in such a way that memory was required, were superior in a

test of discrimination skill to a group getting reproduction training.

The final study demonstrating transfer to distinctive feature training (Samuels, 1970) is one in which kindergarteners were trained to note distinctive features of "b," "d," "p," "q," and then trained to name the letters. The group which received distinctive feature training prior to instructions on hooking-up the letter-name with its symbol experienced fewer failures to learn and learned faster than the group getting discrimination training on the same letters but not on their distinctive features.

Role of Memory

During the process of associational learning, memory for previously presented visual stimuli is required. In explaining human memory, psychologists have developed models which contain three components. These components are visual information store (VIS), short term memory (STM), and long term memory (LTM). The effective life of information in VIS is about 1-second. Information in STM survives for about 15 seconds if it is not recoded or rehearsed. Information in LTM survives for an extended period of time.

When a stimulus is flashed, it is placed in VIS and stored briefly on the retina as an after-image (Sperling, 1960), somewhat like an image on a photographic point. However, the difference between VIS and a photographic print is that VIS decays in about 1 second. If a second stimulus is flashed prior to processing the first

image in VIS, the first image can be erased. The implication for reading is that one function of the fixation pause is to prevent new stimuli from interfering with the processing of the image in VIS (Gilbert, 1959).

Bartlett's (1932) work on memory provides some clues as to how visual memory is stored. Bartlett presented a picture of an animal that resembled a cross between an owl and a cat. He then had his subjects draw the object from memory. At times the drawings resembled a cat, at other times it resembled an owl. Apparently, the visual image is encoded verbally as either "cat" or "owl", depending on how the original image is recoded. The reproduced drawing resembles the encoded verbal description.

Additional evidence as to the fate of visually presented stimuli is presented by Conrad (1964), and Steinheiser (1970). In all cases, visual stimuli were presented (ex. letters) and reports were solicited. In numerous cases the errors were due to auditory confusions, or to verbal substitutions or to errors in manner and place of vocal articulation, suggesting that the visual stimuli were encoded verbally. Thus, it seems visual information is recoded as a verbal surrogate. According to Conrad (1964), the information stored in STM is auditory in form.

Visual information in VIS and auditory information in STM are both rapidly lost. To reduce this loss, the VIS is recoded auditorily. Obviously, as we saw with Bartlett's, the accuracy of the verbal description will affect the accuracy of the memory. However, to prevent loss of verbal information, rehearsal must take place; this rehearsal

being in the form of sub-vocal repetition of a verbally encoded item.

Although visual stimuli can be encoded verbally, there is suggestive evidence that visually presented stimuli do not necessarily have to be encoded verbally in order to be stored. Haber, et.al., (1964) reported that about 8% of elementary school subjects had eidetic images which lasted at least 40-seconds. These subjects when reporting their images appeared to be scanning as they reported fine detail and the images were positively colored. Doob (1964, 1965) also reported eidetic imagery among adult African Ibos. It seems that eidetic imagery in Western culture is lost at maturity due to acculturation.

If all visual stimuli had to be encoded verbally for memory storage in the human, it would be difficult to explain visual recognition memory in the infant prior to his acquisition of a functional language. It may be that visual information is stored as an image prior to the development of a functional language. With the onset of language, visual stimuli are encoded verbally. In addition, phenominological evidence from animals, where language is absent, indicates animals have visual memory in the absence of language. Furthermore, humans do have vividly colored images in their dreams, and they occasionally have images when awake. Such evidence suggests that a model of human memory should include visually stored images.

Conclusions and Suggestions for Improving Visual Memory and Paired-Associate Learning

Contrary to notions which hold that attention and memory are relatively static and passive processes, we find that they are active processes and involve the use of strategies. It has been suggested that attentional processes of the child undergo developmental changes. At first, the child's attention can be captured and held by environmental stimuli. But, as the child matures, attention becomes more exploratory and less captive. In conjunction with the growing ability to determine upon which stimuli to focus attention, the child develops strategies for information search. The strategies usually involve the search for invariants.

Earlier in this paper I suggested that improvement over time in memory functioning of poor readers was largely due to the learning of better strategies. Gelman (1967) has been able to demonstrate with children that ability to do Piagetian conservation problems can be trained rather quickly by teaching the non-conservers strategies for directing attention to those dimensions which are essential for success on the problem. Other studies cited above indicate that training on noting distinctive features transfers to improved associational learning. In fact, Anderson and Samuels (1968) proposed that the inferior visual memory scores of their poor readers probably resulted from failure to note critical features in the stimuli.

Whereas we know that there are individual differences in learning rate, we also know that when amount learned is controlled, differences

in memory become insignificant. Shuell and Keppel (1970) write "The results indicate that individual differences in long-term retention are at best minimal when subjects are equated for degree of original learning." The important point I would like to make here is that poor visual memory, which we know retards associational learning, probably reflects the fact that the subjects had not learned well in the first place, and the type of learning I am referring to is perceptual learning.

The facilitating effect of noting distinctive features during perceptual learning on visual memory is suggested by the work of memory artists. Psychologists, in general, have ignored the memory artists, and have failed to study how their memory feats are accomplished. In the gambling casinos around the Mediterranean, there there are guards employed who stand at the door and whose job it is to recognize gamblers who must be kept out. The number of gamblers who must be kept out is substantial, and what makes the job particularly difficult is that many of the gamblers have never before been seen by the guards. The trick behind this visual memory feat has been borrowed from the caricaturist. Each gambler who must be kept out has a caricature drawing which emphasizes his distinguishing features. These drawings are sent to all the casinos where they are studied by the guards. Having studied the distinctive features of each caricature, the guards attempt to match the features with those who seek admission to the casino.

The techniques used by the casino guards to facilitate identification are very similar to those used by bird watchers. The bird

watcher studies simplified drawings which contain arrows pointing to distinctive markings. Birds which tend to be confused with one another are placed together on the page so the reader can more easily note the dimensions of difference. This procedure of putting similar birds together for comparison purposes is what we do in simultaneous matching-to-sample. The arrows guarantee that the student will easily and quickly focus on the appropriate cues.

It seems that the studies reviewed suggest several ways for improving visual memory and for understanding why there are differences in visual memory. Individual differences in visual memory functioning would appear to result from what was learned and the degree of learning during the perceptual learning phase. If we wish to improve visual memory and paired-associate learning, we should start with the perceptual learning phase.

During the perceptual learning phase, if simultaneous matching-to-sample training is given, learning distinctive features is facilitated. The reason for facilitation is that when stimuli are available for direct comparison, it is easier to discover the dimensions of difference. To guarantee that the student will quickly note the dimensions of difference, some device for directing attention can be used. On the other hand, successive matching-to-sample training, which depends upon memory, seems to bring about schemata learning. For our purposes, both distinctive feature and schemata learning are to be encouraged.

The goal underlying the teaching of these reading sub-skills in many classrooms appears to be accuracy. Although accuracy is

indeed a necessary condition, it is not sufficient for the goals we wish the student to reach. Our goal is for accuracy and automaticity. When actually reading, where there is accuracy without automaticity, there is frequently an overload on attention and memory, and comprehension suffers. Students who can decode accurately without comprehending what they have read, are probably using so much of their limited attention capacity for decoding, that their memory for what was read tends to suffer. Students who can comprehend a spoken message should be able to comprehend that same message when printed, providing their decoding is effortless.

As mentioned earlier, many children experience early failure in reading because they fail to master the paired-associate reading sub-skills. When the teacher presents letter A and says "A" she operates as though paired-associate learning were a single stage process, which we know it is not. In teaching these reading sub-skills, we must teach them as a multi-stage process.

How can we accomplish these goals of teaching paired-associate learning as a multi-state process, facilitating distinctive feature and schemata (chunk) learning, and bringing about accuracy and automaticity? First of all, the S-R hook-up phase in paired-associate learning must be separated from the perceptual learning phase. Perceptual learning itself should be broken into two stages, the distinctive feature learning phase and the chunking phase. To bring about distinctive feature learning, the students should be given simultaneous matching-to-sample training. During this phase, highly similar figures should be grouped together. Once the student has

learned the distinctive features chunk learning can begin. To accomplish chunk learning, successive matching-to-sample training should be given, in which case the student matches from memory. If the student takes a long time to make a memory match, he has not reached the automaticity stage. The memory match should be as fast as if he were matching common objects. When the automaticity stage is reached, we can assume the perceptual learning stage has been completed. It is at this point that the hook-up stage is introduced.

The pilot work using this method to improve paired-associate learning has been encouraging. At the present time teachers are teaching these paired-associate reading sub-skills with little understanding of how to do so effectively. We hope to offer them a rationale and a proven method.

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Table 1

Intercorrelations Among Various Standardized Scores, Experimental Tasks, & Intelligence

Variables		Intercorrelations								
		2	3	4	5	6	7	8	9	10[a]
1	IQ	.38**	.56**	.46**	.43**	.41**	.21	.12	.25*	.25*
2	Vocab.		.82**	.96**	.89**	.76**	.84**	.30*	.07	.53**
3	Comp.			.91**	.88**	.73**	.67**	.27*	.14	.57**
4	Total Rdg.				.93**	.78**	.81**	.31**	.13	.58**
5	Arith. Reas.					.76**	.74**	.29*	.16	.56**
6	Arith. Comput.						.66**	.13	.01	.42**
7	Spelling							.33**	.04	.57**
8	VRM								.26*	.43**
9	AA									.34**
10	PAL									

* p .05

** p .01

[a] Log_{10} used to normalize data

Table 2

Percentage of Orientation Errors Made by

Good and Poor Readers on the PAL Task

Reading Achievement	Orientation Error		
	U-D	L-R	180°
Poor Readers[a]	53%	29%	18%
Good Readers	55%	25%	20%

[a]Note that each row adds up to 100%.

Table 3

Probability of Three Kinds of Orientation Recognition Errors for Good and Poor Readers on the VRM Transformations

Reading Achievement	Orientation Error			Standards
	U-D	L-R	180°	
Poor Readers	.55	.40	.24	.24
Good Readers	.39	.37	.40	.16

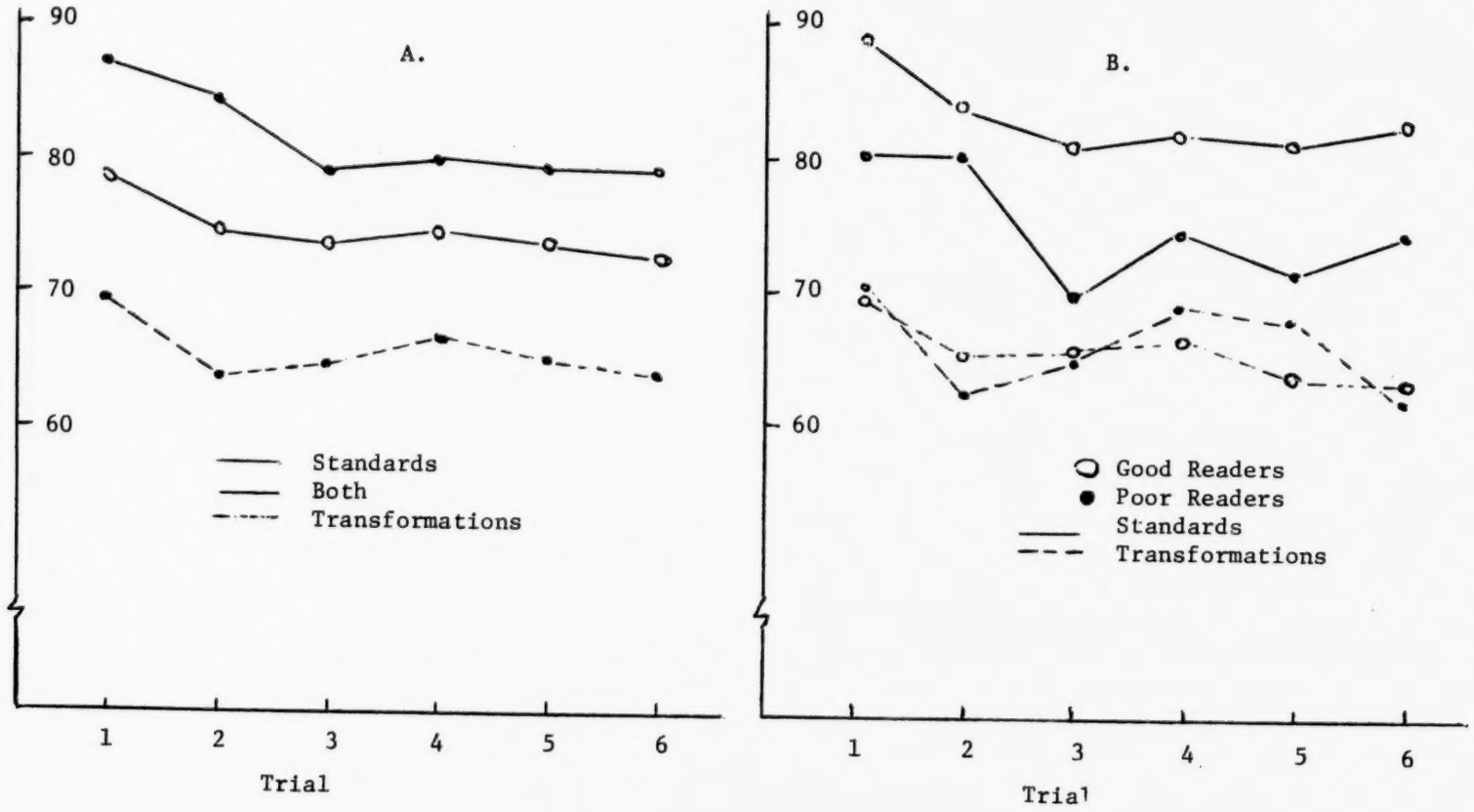

Figure 1. VRM task learning curves for various stimuli and subjects.

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